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SEED PRODUCTION OF WESTERN WHITE PINE.[1]

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PROBLEMS INVOLVED IN DETERMINING SEED PRODUCTION.

When, several years ago, an attempt was made by the Forest Service to collect seed on a large scale for forestation purposes, it was keenly realized for the first time how little knowledge exists in this country regarding the seed production of our trees and the factors which influence it. One should be able to foretell with a reasonable degree of certainty the amount of seed which different species will produce at definite intervals. Aside from the practical value of such knowledge, it is of the greatest scientific interest. Our knowledge of the life history of forest trees will be incomplete until the mysterious occurrence of seed years and the factors that influence them are fully understood. Of all the forest problems, seed production is the most difficult one to solve. This may be readily inferred from the fact that although seed production excited great interest on the part of European foresters even in the early days, and several attempts were made to penetrate into the mystery of it, little as yet is known regarding the factors which influence the seed production of even the few European species.

The investigation of seed production of forest trees consists of four distinct problems: (1) The determination of the amount of the seed crop, (2) the determination of the periodicity of seed production, (3) the determination of the various external and internal factors which affect the amount and the periodicity of seed production, and (4) the solution of the biological problem of seed production. Each of these problems must be solved in the order indicated, since the solution of one furnishes the basis for the solution of those which follow.

The first and immediate problem is to determine the amount of seed produced by each species. This may not be as simple an under-

[1] *Pinus monticola* Dougl.

NOTE.—This bulletin contains a report upon an investigation of the seed production of western white pine and a discussion of the method of measuring the seed crop.

taking as it seems. Should the seed crop be estimated ocularly or actually measured on representative trees or sample plots? If it is to be measured, what is to be taken as the unit of measure—the number of cones produced by a few individual trees, the number of cones produced per unit of area, or the quantity of germinable seed produced by individual trees on a given area?

When a method is agreed upon, the problem of the periodicity of seed crops can be attacked. To solve this problem, repeated comparable investigations of the first problem carried on for years is necessary.

In the solution of the third problem there enters the determination, first, of the external factors such as climate, soil, exposure, light, injury, and destruction of seed by animals and fungi, and, second, of internal factors, such as composition, age, density, and health of the stand. The solution of this complicated question, or rather of this series of complicated questions, requires systematic, parallel, and uninterrupted series of investigations, which can not be undertaken by one individual, but must be carried on by permanently organized forest experiment stations.

The fourth problem, the solution of which is the final aim of the whole investigation, is the most difficult of all, and requires, in addition to the other lines of work, a series of chemical, physiological, and anatomical investigations.

In this paper an attempt will be made to discuss merely the method of measuring seed crops.

METHOD EMPLOYED IN MEASURING THE SEED CROP.

The production of seed in forest trees is not a function of an individual tree, but really of the whole stand, since the development of the life processes of each tree is determined by the density, composition, and age of the stand, and by the position of the tree in the stand. Therefore, in determining the amount of the seed crop, the quantity of seed produced per unit of area, and not the amount produced by individual trees, should be made the basis of measurement. Further, the cone production can not alone serve as a basis for measuring the seed crop. The seed production must be measured not by the quantity of cones but by the amount of seed produced, because the final aim in the study of seed crops is not the cones but the seed. The quality of seed, therefore, viz, its viability, must be taken into account. Two stands may produce different quantities of cones per tree, yet the stand with the smaller average number of cones per tree may furnish more germinable seed than the stand with the larger number of cones. Barren seed are biologically nothing but impurities, and it would therefore be a mistake not to leave them out of con-

sideration in determining the amount of seed production. Thus, in measuring the seed crop, three things must be determined: (1) The seed production for the stand per unit of area (not for individual trees), (2) the quantity of seed, and (3) viability of the seed. The weight of germinable seed per unit of area must be accepted as the standard for measuring seed crops. If a is the weight of clean air-dried seed obtained from 1 acre, and p is their germination per cent, then the seed crop, or x, may be expressed by the formula $x = ap$.

Since the aim is to determine the amount of seed produced per unit of area, the best method of studying seed production is by means of sample areas. These areas may be from one-quarter of an acre to one-half of an acre in extent, in accordance with the density of the stand. Each sample area, however, should include at least 100 trees of the principal species composing the stand.

It would, of course, be more accurate to gather cones and obtain the seed from all of the trees on the sample area. This, however, would necessitate the cutting down of the trees, which is not always practicable or possible. Moreover, this operation would require a great deal of time, which would make such an investigation difficult. For this reason it is preferable to collect the cones and extract the seed only from sample trees.

It is a well-established fact that light is a necessary condition for seed production, and observations show that the greater the amount of light received by the tree the greater is its crown development and the amount of seed produced. It may be already accepted a priori that individual trees in a stand do not produce equal amounts of seed, but vary in accordance with their crown development. In the selection of the sample trees, therefore, one must be guided by the form and development of the crown of the individual tree. In the different species the different parts of the crown have varying importance; thus in Douglas fir the upper part of the crown is of the most importance, since it is there that the largest number of cones are developed; in other species it may be the extremities of the largest lower branches.

In order that the amount of seed obtained from the sample trees should, when multiplied by the total number of trees on the sample plot, actually represent the amount of seed produced on the plot, the sample trees must include representatives of all groups of trees which differ in any way in their crown development. With this end in view, all the trees on the sample plot are divided into groups in accordance with their crown development, and their diameters tallied. From these groups the sample trees are selected. As a basis for dividing the trees into groups in accordance with their crown development, the ordinary classification into dominant (I), codominant

(II), intermediate (III), oppressed (IV), and suppressed (V) may be followed. Since, however, the crown development of trees in the codominant and intermediate classes may not be uniform, these two classes may be subdivided and designated by the letters *a*, *b*, *c*, and *d*. In this way there may be from seven to ten classes or groups of trees.

At the time the trees are measured and divided into groups a note is made for each tree as to whether or not it is bearing cones. These data, which are very interesting in themselves, become absolutely essential in case of partial seed production, when not all of the trees bear cones.

In the work of dividing the trees into groups, the investigator must carefully examine each crown from all sides, observing its habitus. Experience has taught that in order to avoid errors of crown classification the total number of trees on a sample plot must not exceed 100. The size of the sample plot will depend, therefore, upon the age, density, and composition of the stand.

The enumeration of the trees may be made by marking each tree with white paper tags, and the record kept on a form similar to the one given below:

Number.	Diameter.	Class.	Cones present (+) or absent (−).
	Inches.		
1	25	III*a*	+
1	13	V	−
Aspen	27		

When in a mixed stand a tree of secondary species occurs, its name should be given in the first column, but columns 3 and 4 left blank. After the number of trees in each class is computed, a certain number of sample trees are selected from the various classes. For ordinary investigations, 10 per cent of the total number of trees on the sample plot may be sufficient. For more intensive investigations, however, a larger percentage should be taken.

The more carefully the division into classes is done and the more uniform the crowns of each class, the easier it is to select the sample trees. It is advisable to select sample trees separately for each class—that is, first select the trees of Class I, then take up the next class, and so on.

When not all trees in the stand are bearing cones, the sample trees should be selected from the cone-bearing ones, and, in determining the amount of seed production, the percentage of seed-bearing trees for each group must be taken into account.

The sample trees are felled, care being taken in falling that they do not touch the crowns of other trees and thus knock off their own

cones or those of their neighbors. From the felled sample trees all the cones are gathered very carefully, those which still hang on the branches as well as those which were knocked off in felling the tree. It is necessary to avoid collecting cones which were knocked off from other trees. This can often be very readily accomplished, since the cones of each tree differ from those of others in size and form, especially in the case of western white pine. The cones gathered from each sample tree are put in separate sacks, properly labeled, and after being slightly dried at ordinary room temperature are subjected to further investigation.

The total height and age and health of each of the sample trees are determined, the number of cones from each counted, their lengths measured, and their volumes and green weights determined. The cones are then dried and the seed extracted. Coniferous tree seeds are separated from their wings, cleaned, and weighed. If there is any foreign matter present its percentage is determined by weighing several grams of the sample, then cleaning it of all foreign matter and reweighing. After the seeds are cleaned, 200 are taken, their weights determined to one one-hundredth of a gram, and these are then germinated. After the germination percentage is determined, the amount of seed per unit of area—for instance, an acre—can be ascertained by means of the formula, $x = ap$.

SEED PRODUCTION OF WESTERN WHITE PINE.

The method of investigation described was applied in 1911 to the study of seed-bearing characteristics of the western white pine in Idaho on the Kaniksu and Coeur d'Alene National Forests, where this pine reaches its optimum development. In all there were located four sample plots, three on the Kaniksu and one on the Coeur d'Alene Forest. About 10 per cent of the white-pine trees of the different crown classes which bore cones were felled, the cones carefully gathered, and kept separately for each tree. The seed from each tree was extracted by hand and its purity and germinability determined. The results for each sample plot follow.

TABLE 1.—*Classification of trees according to character of crown and presence or absence of cones; number of cones and amount of seed produced by sample trees, and total seed production on plot No. 1, Kaniksu National Forest (area, one-half acre).*

CROWN CLASSIFICATION OF TREES AND NUMBER BEARING CONES.

Diameter breast high (inches).	Number of trees, by crown class.					Trees with cones.		Trees without cones.	
	Class I.	Class II.	Class III.	Class IV.	Class V.	Number.	Per cent.	Number.	Per cent.
1 to 5					4			4	100
6 to 8				2	3			5	100
9 to 10			2	5	1			8	100
11 to 12			2	3				5	100
13 to 14		1	2	2		2	40	3	60
15 to 16									
17 to 18		1	1			1	50	1	50
19 to 20	1	5	2			6	75	2	25
21 to 22	3	5				7	87	1	13
23 to 24	1	6				6	86	1	14
25 to 26	7	2				8	89	1	11
27 to 28	4					4	100		
29 to 30	1	1				1	50	1	50
31 to 32	3					3	100		
33 to 34									
35 to 36	1					1	100		
Total	21	21	9	12	8	38	[1] 54	33	[1] 46
Per cent	30	30	12	17	11	54		46	
Per cent of each class with cones	100	83	18	0	0				

NUMBER OF CONES AND AMOUNT OF SEED PRODUCED BY SAMPLE TREES.

Tree No.	Crown class.	Diameter.	Age.	Height.	Cones open or closed.	Number of cones by inch lengths.			
						3 to 4 inches.	5 to 6 inches.	7 to 8 inches.	Total.
		Inches.	*Years.*	*Feet.*					
1	I	28	230	166	Closed	9	139	77	225
2	I	28	230	152	do	2	26	24	52
3	I	21	223	147	do		4	17	21
					Open		4	37	41
1	II	24	215	154	Closed		14	6	20
2	II	21	200+	146	do	4	5		9
					Open	1	4		5
3	II	21	200+	152	Closed	5	55	9	69
1	III	14	[2] 200	104	do			7	7
Total (7 trees)						21	251	177	449

Tree No.	Average length of cone.	Total weight of cones.	Total volume of cones.	Weight of clean seed.	Number of clean seed per pound.	Per cent of germination.	Per cent germinating in first 144 days of test.
	Inches.	*Pounds.*	*Bushels.*	*Grams.*			
1	5.8	23.3	1.215	330.27	38,069	22	19.0
2	6.2	4.5	.325	58.58	30,362	45	31.0
3	7.0	1.5	.204	8.79	31,680	18	13.5
	7.3	3.5	.478	17.10	29,813		
1	6.1	2.1	.137	40.21	26,880	52.5	33.5
2	4.4	.2	.027	.82	35,200	26	25.0
	5.0	.15	.045	4.02	56,960		
3	5.3	4.1	.341	94.32	33,876	67.5	34.0
1	7.2	.7	.090	13.06	24,320	56	33.0
Total (7 trees)	[1] 5.8	40.1	2.862	567.19			

[1] Per cent of total.

[2] Rotten.

TABLE 1.—*Classification of trees according to character of crown and presence or absence of cones; number of cones and amount of seed produced by sample trees, and total seed production on plot No. 1, Kaniksu National Forest (area, one-half acre)*—Continued.

TOTAL SEED PRODUCTION.

Crown class.	Total trees.		Total sample trees.		Yield from sample trees.			Yield of germinable seed.		
					Cones.	Cleaned seed.	Germinable seed.[1]	Per plot.	Per acre.	
	No.	*Per ct.*	*No.*	*Per ct.*	*Bush.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*No.*
I	21	30	3	14	2.22	414.75	103.68	725.78	1,451.56	114,408
II	21	30	3	14	.55	139.38	86.04	487.54	975.086	68,680
III	9	12	1	11	.09	13.06	7.31	14.63	29.26	1,704
IV	12	17	.....	.....	.....	.....	.....	.....	.....	.....
V	8	11	.....	.....	.....	.....	.....	.....	.....	.....
Total	71	100	7	10	2.86	567.19	.....	1,227.95	[2] 2,455.906	184,792

[1] Weight of pure seed multiplied by their percentage of germination. [2] Equivalent to 5.4 pounds.

TABLE 2.—*Classification of trees according to character of crown and presence or absence of cones; number of cones and amount of seed produced by sample trees, and total seed production on plot No. 2, Kaniksu National Forest (area, one-half acre).*

CROWN CLASSIFICATION OF TREES AND NUMBER BEARING CONES.

Diameter breast high (inches).	Number of trees, by crown class.					Trees with cones.		Trees without cones.	
	Class I.	Class II.	Class III.	Class IV.	Class V.	Number.	Per cent.	Number.	Per cent.
1 to 5	.....	.....	.....	.....	3	.....	.....	3	100
6 to 8	.....	.....	.....	2	18	.....	.....	20	100
9 to 10	.....	.....	.....	8	2	.....	.....	10	100
11 to 12	.....	.....	3	6	.....	.....	.....	9	100
13 to 14	.....	.....	5	5	.....	2	20	8	80
15 to 16	.....	3	3	.....	.....	4	66	2	34
17 to 18	.....	7	1	.....	.....	7	87	1	13
19 to 20	2	6	1	.....	.....	8	89	1	11
21 to 22	5	1	.....	.....	.....	6	100	.....	.....
23 to 24	5	.....	.....	.....	.....	5	100	.....	.....
25 to 27	1	.....	.....	.....	.....	1	100	.....	.....
Total	13	17	13	21	23	33	38	54	62
Per cent	15	20	15	24	26	38	.....	62	.....
Per cent of each class with cones	100	94	30	0	0	.....	.....	.....	.....

NUMBER OF CONES AND AMOUNT OF SEED PRODUCED BY SAMPLE TREES.

Tree No.	Crown class.	Diameter.	Age.	Height.	Cones open or closed.	Number of cones, by inch lengths.				
						3 to 4 inches.	5 to 6 inches.	7 to 8 inches.	9 to 10 inches.	Total.
		Inches.	*Years.*	*Feet.*						
1	I	20	144	150	Closed	.....	4	6	1	11
2	I	22	145	164	Open	1	17	5	.....	23
					Closed	2	39	19	.....	60
1	II	20	145	160	Open	.....	6	8	1	15
					Closed	.....	.....	12	5	17
2	II	16	147	141	Open	.....	5	3	.....	8
3	II	18	146	144	do	.....	.....	14	3	17
					Closed	.....	1	2	20	3	26
1	III	14	134	133	Open	.....	2	1	1	4
2	III	16	145	134	do	.....	2	.....	.....	2
3	III	17	144	138	Closed	.....	11	1	1	13
Total (8 trees)						4	88	89	15	196

TABLE 2.—*Classification of trees according to character of crown and presence or absence of cones; number of cones and amount of seed produced by sample trees, and total seed production on plot No. 2, Kaniksu National Forest (area, one-half acre)*—Continued.

NUMBER OF CONES AND AMOUNT OF SEED PRODUCED BY SAMPLE TREES—Contd.

Tree No.	Average length of cone.	Total weight of cones.	Total volume of cones.	Weight of clean seed.	Number of clean seed per pound.	Per cent of germination.	Per cent germinating in first 144 days of test.
	Inches.	*Pounds.*	*Bushels.*	*Grams.*			
1	6.6	1.0	0.077	14.910	31,200	63.5	25.0
2	5.7	1.5	.171	12.861	24,352	56.5	37.5
	5.8	4.8	.410	63.659	26,458		
1	6.0	1.2	.171	8.670	27,520	37	6.0
	7.8	1.9	.189	53.421	26,619		
2	5.9	.5	.080	.555	37,600	[1]	.....
3	7.7	1.6	.273	18.283	31,467	40	10.0
	7.2	2.6	.273	25.035	26,187		
1	7.1	.2	.060	2.364	31,520	15.5	13.0
2	5.5	.1	.015	1.196	38,800	[1]	.....
3	6.0	1.0	.070	33.522	26,920	34.5	24.5
Total (8 trees)	6.4	16.4	1.789	234.476	.....	.....	.....

TOTAL SEED PRODUCTION.

Crown class.	Total trees.		Total sample trees.		Yield from sample trees.			Yield of germinable seed.		
					Cones.	Cleaned seed.	Germinable seed.[2]	Per plot.	Per acre.	
	No.	*Per ct.*	*No.*	*Per ct.*	*Bush.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*No.*
I	13	15	2	15	0.66	91.43	52.702	342.563	685.126	40,352
II	17	20	3	18	.99	105.96	40.523	216.128	432.256	26,016
III	13	15	3	23	.14	37.08	12.344	16.460	32.920	2,032
IV	21	24	.....	.....	.....	.....	.....	.....	.....	.....
V	23	26	.....	.....	.....	.....	.....	.....	.....	.....
Total	87	100	8	11	1.79	234.47	.....	575.151	[3]1,150.302	68,400

[1] Not tested.
[2] Weight of pure seed multiplied by their percentage of germination.
[3] Equivalent to 2.5 pounds.

TABLE 3.—*Classification of trees according to character of crown and presence or absence of cones; number of cones and amount of seed produced by sample trees, and total seed production on plot No. 3, Kaniksu National Forest (area, one-half acre).*

CROWN CLASSIFICATION OF TREES AND NUMBER BEARING CONES.

Diameter breast high (inches).	Number of trees, by crown class.					Trees with cones.		Trees without cones.	
	Class I.	Class II.	Class III.	Class IV.	Class V.	Number.	Per cent.	Number.	Per cent.
1 to 5	.....	.....	.....	.....	2	.....	.....	2	100
6 to 8	.....	.....	.....	8	10	.....	.....	18	100
9 to 10	.....	.....	2	20	2	.....	.....	24	100
11 to 12	.....	2	6	6	.....	2	15	12	85
13 to 14	1	9	8	.....	.....	9	50	9	50
15 to 16	1	8	2	.....	.....	7	64	4	36
17 to 18	7	3	.....	.....	.....	9	90	1	10
19 to 20	1	.....	.....	.....	.....	1	100	.....	.....
21 to 22	.....	.....	.....	.....	.....	.....	.....	.....	.....
24	.....	.....	.....	.....	.....	.....	.....	.....	.....
29	.....	.....	.....	.....	.....	.....	.....	.....	.....
Total	10	22	18	34	14	28	28.5	70	71.5
Per cent	10	23	18	35	14	28.5	.....	71.5	.....
Per cent of each class with cones	100	66	17	0	0	.....	.....	.....	.....

TABLE 3.—*Classification of trees according to character of crown and presence or absence of cones; number of cones and amount of seed produced by sample trees, and total seed production on plot No. 3, Kaniksu National Forest (area, one-half acre)*—Continued.

NUMBER OF CONES AND AMOUNT OF SEED PRODUCED BY SAMPLE TREES.

Tree No.	Crown class.	Diameter.	Age.	Height.	Cones, open or closed.	Number of cones, by inch lengths.				
						3 to 4 inches.	5 to 6 inches.	7 to 8 inches.	9 to 10 inches.	Total.
		Inches.	*Years.*	*Feet.*						
1	I	18	150	151	Closed		3	3	1	7
					Open		3	8	2	13
2	I	18	130	139	Closed		8	9		17
1	II	17	145	136	do		2	11	3	16
					Open			12	5	17
2	II	13	153	129	Closed		4	2		6
3	II	15	145	134	do		5	5		10
[1]	III									
Total (5 trees)							25	50	11	86

Tree No.	Average length of cone.	Total weight of cones.	Total volume of cones.	Weight of clean seed.	Number of clean seed per pound.	Per cent of germination.	Per cent germinating in first 144 days of test.
	Inches.	*Pounds.*	*Bushels.*	*Grams.*			
1	6.9	0.8	0.056	14.180	31,744	19.5	13.5
	6.9	1.1	.183	8.106	32,000		
2	6.3	1.4	.255	10.183	26,960	36.5	22.5
1	7.4	1.6	.255	9.280	28,267	46.5	42.0
	7.7	1.7	.292	13.855	25,472		
2	5.5	.5	.045	6.130	34,560	22	18.5
3	6.5	1.0	.073	14.385	29,312	35.5	23.0
[1]				6.130	34,560		
Total (5 trees)	6.9	8.1	1.159	82.249			

TOTAL SEED PRODUCTION.

Crown class.	Total trees.		Total sample trees.		Yield from sample trees.			Yield of germinable seed.		
					Cones.	Cleaned seed.	Germinable seed.[2]	Per plot.	Per acre.	
	No.	*Per ct.*	*No.*	*Per ct.*	*Bush.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*No.*
I	10	10	2	20	0.49	32.47	8.064	40.320	80.640	5,560
II	22	23	3	14	.66	43.65	17.214	86.070	172.140	10,380
III	18	18				6.13	1.349	4.047	8.094	570
IV	34	35								
V	14	14								
Total	98	100	5	5	1.15	82.25		130.437	[3] 260.874	16,510

[1] Results of tree No. 2, Crown Class II, used for this tree.
[2] Weight of pure seed multiplied by their percentage of germination.
[3] Equivalent to 0.6 pound.

TABLE 4.—*Classification of trees according to character of crown and presence or absence of cones; number of cones and amount of seed produced by sample trees, and total seed production on plot No. 4, Coeur d'Alene National Forest (area, 0.9 acre).*

CROWN CLASSIFICATION OF TREES AND NUMBER BEARING CONES.

Diameter breast high (inches).	Number of trees, by crown class.							Trees with cones.		Trees without cones.	
	Class I.	Class II.	Class IIa.	Class III.	Class IIIa.	Class IV.	Class V.	Number.	Per cent.	Number.	Per cent.
4 to 6						4	7			11	100
7 to 8					6	7	2			15	100
9 to 10				4	10	1				15	100
11 to 12		1	2	10				4	30	9	70
13 to 14		4	3	3				5	50	5	50
15 to 16		9	6		1			12	75	4	25
17 to 18	1	5	3					8	89	1	11
19 to 20	1	3						4	100		
21 to 22	2	1						3	100		
23 to 24	2		1					3	100		
25 to 26	2							2	100		
Total	8	23	15	17	17	12	9	41	41	60	59
Per cent	8	22	15	17	17	12	9	41		59	
Per cent of each class with cones	100	91	73	6	0	0	0				

NUMBER OF CONES AND AMOUNT OF SEED PRODUCED BY SAMPLE TREES.

Tree No.	Crown class.	Diameter.	Age.	Height.	Cones open or closed.	Number of cones, by inch lengths.				
						5 to 6 inches.	7 to 8 inches.	9 to 10 inches.	11 to 12 inches.	Total.
		Inches.	*Years.*	*Feet.*						
1	I	19.8	107	127		2	19	17	1	39
1	II	16.0	84	108		7	25	1		33
1	IIa	14.5	92	100		1	3	6	1	11
1	III	12.2	72	78			1			1
1	IIIa	8.5	80	77						
1	IV	7.2	72	67						
1	V	6.0	83	47						
Total (7 trees)						10	48	24	2	84

Tree No.	Average length of cone.	Total weight of cones.	Total volume of cones.	Weight of clean seed.	Number of clean seed per pound.	Per cent of germination.	Per cent germinating in first 144 days of test.
	Inches.	*Pounds.*	*Bushels.*	*Grams.*			
1	7.97	6.0	0.295	118.901	23,840	61	39
1	6.93	3.8	.215	62.773	29,840	33	24
1	8.45	1.9	.102	38.667	21,771	37.5	19
1	8	.1	.008	2.805	21,920	90	50
1							
1							
1							
Total (7 trees)	7.6	11.8	.620	223.146			

TABLE 4.—*Classification of trees according to character of crown and presence or absence of cones; number of cones and amount of seed produced by sample trees, and total seed production on plot No. 4, Cœur d'Alene National Forest (area, 0.9 acre)*—Continued.

TOTAL SEED PRODUCTION.

Crown class.	Total trees.		Total sample trees.		Yield from sample trees.			Yield of germinable seed.		
					Cones.	Cleaned seed.	Germinable seed.[1]	Per plot.	Per acre.	
	No.	*Per ct.*	*No.*	*Per ct.*	*Bush.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*No.*
I	8	8	1	12	0.295	118.90	72.530	580.240	644.711	33,929
II	23	22	1	4	.215	62.77	20.715	435.015	483.350	31,593
IIa	15	15	1	6	.102	38.67	14.500	159.500	177.222	8,727
III	17	17	1	5	.008	2.80	2.525	2.525	2.806	137
IIIa	17	17	1	5						
IV	12	12	1	8						
V	9	9	1	11						
Total	101	100	7	7	.620	223.14	110,270	1,177.280	[2] 1,308.089	74,386

[1] Weight of pure seed multiplied by their percentage of germination.
[2] Equivalent to 2.9 pounds.

CONCLUSIONS.

The material collected so far is not sufficient to allow of final conclusions. Those here presented are offered chiefly to point out the still unknown factors into which the problem of seed production resolves itself and of demonstrating the suitability of the proposed method for solving them.

1. Perhaps the most striking fact brought out by this investigation is that the different crown classes do not participate equally in the production of seed. Thus 98.8 per cent of all the seed in 1911 was produced by the first two crown classes, while the third contributed only 1.2 per cent. It is interesting to note that though 1911 was a year of a moderately good seed crop, the crown classes IV and V did not bear any seed at all.

If we divide the average percentage of seed production of each crown class by the average percentage of trees in each class, we secure, roughly, the ratios in which the different crown classes of western white pine bear seed.

TABLE 5.—*Distribution of the seed crop of western white pine, by crown classes.*

	Ratios of seed production of crown classes.[1]					
	Class I.	Class II.	Class III.	Class IV.	Class V.	Total.
Plot No. 1.						
Total yield.....per cent..	59.1	39.7	1.2	0	0	100
Number of trees.....do....	30	30	12	17	11	100
Plot No. 2.						
Total yield.....do....	59.5	37.6	2.9	0	0	100
Number of trees.....do....	15	20	15	24	26	100
Plot No. 3.						
Total yield.....do....	30.9	66.0	3.1	0	0	100
Number of trees.....do....	10	23	18	35	14	100
Plot No. 4.						
Total yield.....do....	49.3	50.5	0.2	0	0	100
Number of trees.....do....	8	37	34	12	9	100
Average.....	54.3	44.5	1.2	0	0	100
	15	27	21	22	15	100

[1] Expressed in percentage of seed produced in each crown class of the plot divided by percentage of trees in the crown class.

The ratios of productivity of trees of different crown classes in round figures are 3.5, 1.5, 0.05, 0.0. Thus a tree of crown Class I bears 70 times and a tree of crown Class II 30 times more seed than a tree of Class III.

The participation of the different crown classes in the production of seed may serve as an index of the seed crop. In exceptionally good seed years not only the dominant classes bear seed, but even the oppressed trees have occasional cones, while in poor seed years cones are to be found only in the dominant class (I), and even then not on all trees or parts of their crowns. Between these two extremes range seed crops of various abundance. The abundance of the seed crop can, therefore, be prognosticated very early in the summer by observing in the forest the kind of trees that bear cones. In order to establish a regular yield for the seed production of western white pine, it would be necessary accurately to measure the crop by the method described over several seed years of various intensity. After the seed production for the poorest, moderate, and exceptionally good seed years is ascertained, the determination of whether the crop of a given year is good, fair, or poor can then be forecasted easily and early by merely observing the different crown classes of trees that are bearing cones.

An attempt to penetrate deeper into the causes that determine the average amount of seed produced by an individual tree of each crown class meets with difficulties because of the many counteracting factors, some of which still remain unexplained. Aside from the

length and width of the crown, which has been accepted as a most decisive influence in seed production, there are other factors that affect the amount of viable seed produced by a tree, such as the size of the cones, average number of seed in a cone, size of the seed, its germinability, the age of the tree, and the still little understood individual energy of each tree in producing seed.

2. The largest amount of germinable seed was invariably produced by trees chiefly of the first and also of the second crown class. The largest amount of germinable seed recorded (2½ ounces) belonged to two trees of crown Class I, and in only one case has this amount been closely reached by a tree of crown Class II. Crown development thus seems to be the most important factor in the seed production of trees.

3. The age of the trees evidently has an effect upon the amount and quality of seed produced. Thus the younger trees (in plot No. 4), ranging from 72 to a little over 100 years in age, have produced practically in all three crown classes a larger quantity of germinable seed than the older trees. Apparently the age has also something to do with the average length of the cones, since the younger trees possessed, on an average, longer cones which yielded a larger number of pure seeds per cone than the older trees. The germination percentage was also greater in the younger trees than in the old ones; the highest germination percentage reached (90) was found in a tree 72 years old, while the highest found in the older trees was 67.5.

4. The relation between the length of the cone and the size of the seed (the number of seed per pound) is clearly shown. Thus the longest cones, 8 inches and over, yielded about 22,000 seed to the pound, while cones 5 inches long occasionally yielded as many as 57,000 seed to the pound.

5. The vigor of growth apparently influences favorably the amount and quality of seed produced. Thus trees which grew at the rate of 0.19 of an inch in diameter and about 1.25 feet in height annually produced a larger amount of germinable seed than trees which grew at a slower rate. This, however, may be indirectly the effect of the age of the tree, since the younger trees have not yet passed the period of most rapid growth.

6. While a relation between the size of the seed and its germinative vigor [1] is not clearly brought out, yet there seems to be a tendency for the larger seeds to have the highest germinative vigor. This tendency is shown in Table 6.

[1] The germinative vigor is gauged by the percentage of seed which germinated within 144 days after being sown.

TABLE 6.—*Size of seed and period of rest.*

Number of seeds per pound.	Seed that germinated within 144 days.	Number of seeds per pound.	Seed that germinated within 144 days.
	Per cent.		*Per cent.*
22,000	34.5	31,000	17.5
24,000	36.5	32,000	13.4
25,000	42.0	34,000	26.3
26,000	23.8	35,000	25.0
27,000	21.6	36,000	
28,000	24.0	37,000	
29,000	23.0	38,000	19.0
30,000	22.8		

The failure of such relationship to be clearly apparent is probably due more to deficient field data than to the actual absence of any such relationship.

The size of the seed and the germination percentage are closely connected, as shown by Table 7.

TABLE 7.—*Relation of size of seed to germination.*

Number of seeds per pound.	Average germination.
	Per cent.
25,000	60
30,000	39
35,000	31
40,000	22
55,000	26

The percentage of germination decreases with the increase in the number of seed per pound—with the decrease in size of the seed.

8. Similarly, the length of cone has a perceptible effect upon the quality of the seed, as shown in Table 8.

TABLE 8.—*Relation between length of cones and germination.*

Length of cones.	Average germination.
	Per cent.
4 to 5 inches	26
5 to 6 inches	41
6 to 7 inches	40
7 to 8 inches	43

Thus it is fairly evident that seed from shorter cones possess a lower germination percentage than seed from longer cones.

9. Since the size of the cones goes hand in hand with the weight, the following generalization may be made: *The larger or heavier the cones the larger is the seed, and the larger the seed the greater is the*

germination percentage; therefore, the larger the cones the better is the quality of the seed. This is of importance in seed collection.

10. An idea of the reproductive capacity of a single tree may be gained from the record of the largest yield by an individual white-pine tree, which was 2½ ounces, or 6,000 germinable seed.

11. If from individual trees we turn to stands, we find that normally stocked stands bear from 2½ to 5 pounds of germinable seed per acre, or, assuming an average of 30,000 seed to the pound, from 75,000 to 150,000 germinable seed. The apparently small yield of plot No. 3 (a little over one-half pound) is explained by the overcrowded condition of the stand. The average of 3 pounds, or 90,000 germinable seed, per acre for a moderately good seed year may therefore be accepted as the average seed crop for the white pine on the Kaniksu and Coeur d'Alene National Forests. Applying this average figure to the different forest types found on the Kaniksu and Coeur d'Alene Forests, and assuming that there are 45,000 acres of white-pine land of which plot No. 1 is representative, 20,000 acres of which plot No. 2 is a sample, and 15,000 acres which may be represented by plot No. 3, the total amount of germinable seed produced in 1911 on the Kaniksu Forest would be in the neighborhood of 300,000 pounds.

This amount is for a moderately good seed year. In exceptionally abundant seed years it would be much larger. These estimates, of course, do not take into consideration any possible destruction of seed by insects or disease, either in the cone or flower.

12. It is interesting to compare the total yield of germinable seed with the amount of seed actually collected by the Forest Service. In 1911 the collection of seed was conducted on an extremely large scale, 6,700 pounds being gathered on 20,676 acres. The total amount of clean seed produced during this same year on that area, as ascertained by the study, was 225,368 pounds. The amount collected by the Forest Service constituted, therefore, about 3 per cent of the total amount of seed produced that year. This conveys some idea of the portion of seed which man is able to collect out of the total amount produced by the forest. The remainder is either left on the ground for future natural reproduction or is destroyed by squirrels and other animals.

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